

ANTI-MICROBIAL FIBER AND FIBROUS PRODUCTS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application is a divisional application of Serial No. 09/565,138 filed May 5, 2000 which claims the priority of the following provisional applications: Serial No. 60/136,261, filed May 27, 1999; Serial No. 60/173,207, filed December 27, 1999; Serial No. 60/172,285, filed December 17, 1999; Serial No. 60/172,533, filed December 17, 1999; Serial No. 60/180,536, filed February 7, 2000; Serial No. 60/181,251, filed February 9, 2000; and Serial No. 60/180,240, filed February 4, 2000.

FIELD OF THE INVENTION

[0002] The present invention relates generally to fiber, and, more particularly to a fiber having anti-microbial (and/or anti-fungal) properties which remain with the fiber when used in a fabric product after repeated launderings/uses. More specifically it provides a wholly or partly synthetic fiber and multi- or mono-component anti-microbial and/or anti-fungal synthetic fibers, alone or integrated with other synthetic or natural fibers, using various thermoplastic polymers and additives. It may be a bi-component fiber having either a core-sheath or side-by-side configuration or other configurations (e.g. pie-wedge). One arrangement uses binder fibers, which are staple fiber or filament.

[0003] The present invention further relates to products made wholly or in part of such fiber.

[0004] There is an air filter embodiment which relates to vehicle and aircraft cabin air filters that are made of a wholly or partly synthetic fiber that can be either mono- or multi-component in nature and has anti-microbial properties and can be used with other synthetic or natural fibers to form a variety of fabrics and materials. Such invention provides for filter materials that are resistant to bacterial and fungal growth as well as to the deterioration of the fibers contained in these filter materials.

[0005] There is a fabric embodiment which relates generally to fabric construction, and, more particularly, to fabric having qualities imparted to it which remain for the life of the fabric, such as excellent color fastness without the need for a dye bath.

BACKGROUND OF THE INVENTION

[0010] There is a growing interest today in products which have anti-microbial and anti-fungal properties. There are a number of additives, fibers and products on the market which claim to have these properties. However, many do not have such properties, or the properties do not remain for the life of the product, or they have adverse environmental consequences.

[0011] Various materials have been used in the past to provide anti-microbial and anti-fungal properties to fibers and fabrics.

[0012] Examples of some organic types of anti-microbial agents, are U.S. Patents Nos.: 5,408,022 and 5,494,987 (an anti-microbial polymerizable composition containing an ethylenically unsaturated monomer, a specific one-, di- or tri-functional anti-microbial monomer and a polymerization initiator which can yield an unreleasable anti-microbial polymer from which the anti-microbial component is not released), 5,709,870 (a silver containing anti-microbial agent which comprises carboxymethylcellulose, a crosslinked compound, containing silver in the amount of .01 to 1% by weight and having a degree of substitution of carboxymethyl group of not less than .4 and the anti-microbial agent being a silver salt of carboxymethylcellulose, which is insoluble to water), 5,783,570 (an organic solvent-soluble mucopolysaccharide consisting of an ionic complex of at least one mucopolysaccharide and a quaternary phosphonium, an antibacterial antithrombogenic composition comprising organic solvent-soluble mucopolysaccharide and an organic polymer material, an antibacterial antithrombogenic composition comprising organic solvent-soluble mucopolysaccharide and an inorganic antibacterial agent, and to a medical material comprising organic solvent-soluble mucopolysaccharide).

[0013] Examples of some inorganic types of anti-microbial agents are:

[0014] Japanese Patent No. 1246204 (1988) which discloses an anti-microbial thermoplastic article with copper a compound added to the melted polymer just before extruding, in which the anti-microbial material is said to be resistant to washing.

[0015] U.S. Patent No. 5,180,585 which discloses an antimicrobial with a first coating providing the antimicrobial properties and a second coating as a protective layer. A metal having antimicrobial properties is used including silver which is coated with a secondary protective layer.

[0016] Japanese Patent No. 2099606 (1990) which discloses a fiber with anti-microbial properties made of a liquid polyester and inorganic micro particles of zinc silicate, both being added to the melted polymer after polymerization and just before extrusion.

[0017] The use of anti-microbial agents in connection with thermoplastic material is known from U.S. Patent No. 4,624,679 (1986). This patent is concerned with the degradation of anti-microbial agents during processing. This patent states that thermoplastic compounds which are candidates for treatment with anti-microbial agents include material such as polyamides (nylon 6 or 6,6), polyvinyl, polyolefins, polyurethanes, polyethylene terephthalate, styrene-butadiene rubbers.

[0018] Japanese Patent No. 2091009 (1990) and U.S. Pat No 5,047,448 disclose an anti-microbial thermoplastic polymer with copper or zinc compounds and fine particles of Al, Ag, Fe and Zn compounds and a liquid polyester, in which the anti-microbial material is said to be resistant to washing.

[0019] Japanese Patent No. 2169740 (1990) discloses a thermoplastic fiber such as PET which uses silver, copper or zinc as an anti-microbial agent. There is a cellulose component which reduces the amount of thermoplastic with anti-microbial agent and reduces the cost.

[0020] Examples of inorganic types of anti-microbial agent which have zeolite with silver is disclosed in U.S. Patents Nos. 4,911,898 , 5,094,847, 4,938,958 (use of zeolite with exchangeable ions such as silver and others), 5,244,667 (an anti-microbial composition which involves use of partial or complete substitution of ion-exchangeable metal ion such a silver, copper, zinc and others), 5,405,644 (an anti-microbial fiber having a silver containing inorganic microbiocide and the silver ion is stated to have been supported by zeolite, among other materials, the purpose being to prevent discoloration).

[0021] Various products have been made using anti-microbial fibers. U.S. Patent No. 5,071,551 discloses a water purifier having a secondary filter downstream of its primary filter for removing microorganisms and antimicrobial means disposed between the two filters. use of an anti-microbial agent for a water purifier.

[0022] Japanese Patent No. 6116872 (1994) discloses a suede-like synthetic leather with an anti-microbial agent. It discloses the use of anti-microbial zeolite having an anti-microbial metal ion. It uses two fiber types and includes PET.

[0023] U.S. Patent No. 5,733,949 discloses an anti-microbial adhesive composition for dental use. The composition was made by blending of a polymerizable monomer having alcoholic hydroxy group and water to a dental composition containing an anti-microbial polymerizable monomer and a polymerizable monomer having acidic group, and with a polymerization catalyst. Such composition has capability to improve adhesive strength between the tooth and the restorative material to prevent microbial invasion at the interface and kill microorganisms remaining in the microstructure.

[0024] U.S. Patent No. 5,876,489 discloses a germ-removing filter with a filter substrate and an anti-microbial material dispersedly mixed into the filter substrate. The anti-microbial material is an ion exchange fiber bonded with silver ion. In the ion exchange fiber, silver ions capable of killing living germs through an ion exchange reaction.

[0025] U.S. Patent No. 5,900,258 discloses a method for preventing a microorganism from growing and the breakdown of urea to ammonia on the surface of skin, wall, floor, countertop or wall covering, or in absorbent materials by incorporating an effective amount of naturally-occurring and/or synthetic zeolites. The absorbent materials are diapers, clothing, bedsheets, bedpads, surgical apparel, blankets, filters, filtering aids, wall coverings, countertops, and cutting boards, etc. Use of zeolite preventing bacterial infections and rashes in mammals may compromise cell wall processes including basic transport processes. Zeolites may capture or neutralize electrons and inhibit electron transport through key enzymes of the electron transport chain such as cytochrome oxidase.

[0026] U.S. Patent No. 6,037,057 is for a bi-component fiber in which the cross sectional area of the sheath is less than 28% of the total cross sectional area. It also discloses the use of a slickening agent and use of an anti-microbial agent which is an inert inorganic particle having a first coating with the anti-microbial properties, and a second coating which has protective properties..

[0027] One of the disadvantages of some of the prior art is that the anti-microbial additives are organic and many organic materials either act as antibiotics and the bacteria "learns" to go around the compound, or many of them give off dioxins in use.

[0028] Also, many such additives are applied topically to the fibers or fabrics and tend to wash off or wear off over time and become ineffective. Also, by washing off the additives are placed into the waste water stream.

[0029] There has been little attention to a problem which remains even when the fluids are moved away from the skin. This is the problem caused by microbes which attach to the outer layer which touches the skin even when the fluids move into the absorbent layer. These microbes cause a variety of problems.

[0030] Vehicle and aircraft cabin air filters are vulnerable to the seeding of bacteria and fungi from outside air sources and air conditioning systems, thus providing hospitable sites for their inhibited growth. The latter is especially true since these filters often recirculate cooled air from air-conditioners. Thus, these materials would benefit from having antibacterial and anti-fungal agents incorporated into them. However, most prior art approaches of coating fibers or materials with anti-microbial or anti-fungal agents have limited effect.

[0031] There have been complaints about the "musty air" smell which is noticed when air conditioning equipment is turned on in such cabins. This smell is caused by the growth of mold and bacteria with the air conditioning system.

[0032] There exists a need to develop fabrics and other effective material for use in air filters for vehicle and aircraft cabins that do not cause the development of resistant bacterial strains. There also still exists a need for these filters to have substrates-anti-microbial agent systems that are resistant to being washed away, thus maintaining their potency as an integral part of the filters into which they are incorporated.

[0033] U.S. Patent No. 5,876,489, mentioned above, describes use of a cation exchange to provide a fiber bonded with silver ions, usable in a germ removing filter for sterilizing air for a sterile room such as is used in the manufacture of food products. A problem with using silver zeolite fine particles for such a filter is that the particles fall out and generate dust, thereby

deteriorating the function of a HEPA filter with which it is used. When other methods are used in which the zeolite particles are two microns, with fiber filament having a diameter of 8-15 microns, insufficient zeolite particles are available on the surface of the synthetic fiber filament.

[0034] Several patents describe anti-microbial materials in which the anti-microbial agent is resistant to being washed away. Similarly, U.S. Patent No. 4,919,998 (1990) discloses an anti-microbial medical fabric material for use in surgical gown and scrub suits, sterilization wrappers and similar material that retains its desirable properties after repeated institutional launderings.

[0035] Thus, there still exists a need to develop metal-containing anti-microbial agents that do not cause the development of resistant bacterial strains for incorporation into fibers that are used to make a variety of materials. There also still exists a need for these anti-microbial agents to be resistant to being abraded or washed away, thus maintaining their potency as an integral part of the fibers into which they are incorporated.

[0036] PETG as used herein means an amorphous polyester of terephthalic acid and a mixture of predominately ethylene glycol and a lesser amount of 1,4-cyclohexanedimethanol. It is known that PETG can be used in polycarbonate blends to improve impact strength, transparency, processability, solvent resistance and environmental stress cracking resistance.

[0037] Udipi discloses in U.S. Patents Nos. 5,104,934 and 5,187,228 that polymer blends consisting essentially of PC, PETG and a graft rubber composition, can be useful as thermoplastic injection molding resins.

[0038] Chen et al. in U.S. Patent No. 5,106,897 discloses a method for improving the low temperature impact strength of a thermoplastic polyblend of PETG and SAN with no adverse effect on the polyblends clarity. The polyblends are useful in a wide variety of applications including low temperature applications.

[0039] Billovits et al. in U.S. Patent No. 5,134,201 discloses that miscible blends of a thermoplastic methylol polyester and a linear, saturated polyester or co-polyester of aromatic dicarboxylic acid, such as PETG and PET, have improved clarity and exhibit an enhanced barrier to oxygen relative to PET and PETG.

[0040] Batdorf in U.S. Patent No. 5,268,203 discloses a method of thermoforming thermoplastic substrates wherein an integral coating is formed on the thermoplastic substrate that is resistant to removal of the coating. The coating composition employs, in a solvent base, a pigment and a thermoplastic material compatible with the to-be-coated thermoplastic substrate. The thermoplastic material, in cooperation with the pigment, solvent and other components of the coating composition, are, after coating on the thermoplastic substrate, heated to a thermoforming temperature and the thermoplastic material is intimately fused to the thermoplastic substrate surface.

[0041] Ogoe et al. in U.S. Patent No. 5,525,651 disclose that a blend of polycarbonate and chlorinated polyethylene has a desirable balance of impact and ignition resistance properties, and useful in the production of films, fibers, extruded sheets, multi-layer laminates, and the like.

[0042] Hanes in U.S. Patent No. 5,756,578 discloses that a polymer blend comprising a monovinylarene/conjugated diene black copolymer, an amorphous poly(ethylene terephthalate), e.g. PETG, and a crystalline poly(ethylene terephthalate), e.g. PET, has a combination of good clarity, stiffness and toughness.

[0043] Eckart et al. in U.S. Patent No. 5,958,539 disclose a novel thermoplastic article, typically in the form of sheet material, having a fabric comprising textile fibers embedded therein. The thermoplastic article is obtained by applying heat and pressure to a laminate comprising an upper sheet material, a fabric comprised of textile fibers and a lower sheet material. The upper and lower sheet materials are formed from a co-polyester, e.g. PETG. This thermoplastic article may be used in the construction industry as glazing for windows. One or both surface of the article may be textured during the formation of the articles.

[0044] Currently, many tee shirts, such as the grey athletic shirts, are made by blending in up to 10% of either solution dyed black polyester or stock dyed cotton. The solution dyed polyester has a disadvantage in that the product can no longer be labeled 100% cotton. The stock dyed cotton has the disadvantage in that it is not color fast, especially to bleach, and that it needs to be passed through a dye bath.

[0045] A variety of patents relate to anti-microbial materials being added to materials. For example, U.S. Patent No. 3,959,556 (1976) relates to synthetic fibers that incorporate an anti-microbial agent. U.S. Patent No. 4,624,679 (1986) , mentioned above, uses anti-microbial agents in connection with thermoplastic materials. These materials are formed by mixing polyamide resins, anti-microbial agents, and an antioxidant for reducing the degradation of the anti-microbial agent at the high temperatures necessary for processing.

[0046] Several other patents describe anti-microbial materials in which the anti-microbial agent is resistant to being washed away. U.S. Patent No. 4,919,998 (1990) discloses an anti-microbial material that retains its desirable properties after repeated washings.

[0047] However, these materials have two inherent commercial disadvantages. First, while the anti-microbial agents incorporated into them do show some resistance to repeated washings, these agents do leach out of the materials, primarily because they are not physically incorporated into them. In fact, in many cases, the anti-microbial agents are only loosely bound into the material and are relatively easily washed away or naturally abraded away over time.

[0048] On the other hand if the agents are buried too deeply in the material or homogeneously distributed they will not contact microbes at all and the economics of usage will be adversely affected.

[0049] Second, the anti-microbial agents used in these applications are generally organic substances. The disadvantage of these agents when used as anti-microbial agents is that bacteria can develop a resistance to their action. Thus, one is faced with the emergence of bacterial strains that are no longer affected by these anti-microbial agents which negates the function of these materials.

[0050] U.S. Patent No. 4,923,914 for a Surface-Segregatable, Melt-Extrudable Thermoplastic Composition discloses forming a fiber or film of polymer and an additive in which the additive concentration is greater at the surface. for example when surfactants are added to polymers to impart a special property thereto such as a hydrophilic character to the surface, if the additive is compatible with the polymer there is a uniform concentration of the additive throughout the polymer. In the past such webs have been bloomed to bring the surfactant to the surface. But the

surfactant is incompatible at melt-extrusion temperatures. The patentee describes a process for overcoming this problem.

[0051] However, the process described has not been very usable with anti-microbial agents. For example, see U. S. Patent No. 5,280,167 which describes the '914 patent discussed above and states that previous attempts to apply the teachings thereof to the preparation of non-woven webs having anti-microbial activity were not successful. This '167 patent provides for delayed anti-microbial activity in order to delay the segregation characteristic of the '914 patent from occurring. The additive which is used is a siloxane quaternary ammonium salt, an organic material.

[0052] While these anti-microbial agents are designed to prevent the development of resistant bacterial strains, the use of metal-containing materials presents the added difficulty of being able to successfully disperse the anti-microbial agents throughout the material. Since these metal-containing compounds exist as fairly large size particles (10 microns and greater), the ability to evenly mix or distribute them is limited. In addition, because of this size problem, these substances must necessarily be applied to the surfaces of materials instead of being incorporated into them. The latter causes the additional disadvantage of making the applied anti-microbial agents relatively labile to washings or abrasion.

[0053] Thus, there still exists a need to develop anti-microbial non-woven sheet material and fabrics for various uses that do not cause the development of resistant bacterial strains. There also still exists a need for these filters to have substrates-anti-microbial agent systems that are resistant to being washed away, thus maintaining their potency as an integral part of the filters into which they are incorporated.

[0054] U.S. Patent No. 4,371,577 for an anti-microbial carpet containing amino acid type surfactant is incorporated into fibrous materials prior to or after fabrication into a carpet using an organic material. The fibrous materials can be polyamide acrylic, polyester or polypropylene fibers. The preparation is accomplished in two manners. The first is that the pile yarns, the carpet foundations or the yarns for carpet foundation are subjected to the impregnation treatment with a

surfactant, and the other is that a carpet fabricated from fibrous materials is impregnated with an organic material.

[0055] U.S. Patent No. 5,762,650 for a biocide plus surfactant for protecting carpets where the dyeing and anti-microbial finishing is performed simultaneously. The anti-microbial agent is an organic material.

[0056] While there are known anti-microbial agents which are said to be designed to prevent the development of resistant bacterial strains, the use of metal-containing materials presents the added difficulty of being able to successfully disperse the anti-microbial agents throughout the fibers. Since these metal-containing compounds exist as fairly large size particles (10 microns and greater), the ability to evenly mix or distribute them is limited. In addition, because of this size problem, these substances must necessarily be applied to the fibers instead of being incorporated into them. The latter causes the additional disadvantage of making the applied anti-microbial agents relatively labile to washings.

[0057] U.S. Patent No. 5,709,870 (1998), mentioned above, discloses a silver-containing anti-microbial agent that has good affinity to the fiber and is stable to heat and light. The anti-microbial consists of silver bound to carboxymethylcellulose in the amount of 0.01 to 1.0 percent silver by weight that is applied to the fibers.

[0058] While these anti-microbial agents are designed to prevent the development of resistant bacterial strains, the use of metal-containing materials presents the added difficulty of being able to successfully disperse the anti-microbial agents throughout the fibers. Since these metal-containing compounds exist as fairly large size particles (10 microns and greater), the ability to evenly mix or distribute them is limited. In addition, because of this size problem, these substances must necessarily be applied to the fibers instead of being incorporated into them. The latter causes the additional disadvantage of making the applied anti-microbial agents relatively labile to washings.

[0059] Thus, there still exists a need to develop metal-containing anti-microbial agents that do not cause the development of resistant bacterial strains for incorporation into fibers that are used to make a variety of materials. There also still exists a need for these anti-microbial agents to be

resistant to being abraded away, thus maintaining their potency as an integral part of the fibers into which they are incorporated. In the event they are not disposable, they need to be resistant to washings.

SUMMARY OF THE INVENTION

[0060] It is an object of the present invention to provide an anti-microbial fiber in which the anti-microbial agents are efficacious and adhere to the fiber and are greatly resistant to washing off or wearing off of the fiber or fabric to which they are applied.

[0061] It is also an object of the present invention to provide an anti-microbial fiber in which the anti-microbial additives are inorganic.

[0062] It is another object of the present invention to provide a fiber with anti-microbial properties in which the anti-microbial agent is applied to certain areas, or has higher concentrations in certain areas, to reduce the amount of the anti-microbial agent which needs to be used and thus lower the cost of such fiber and/or a product including such fiber.

[0063] It is another object of the present invention to provide an anti-microbial fiber combined with non-anti-microbial fibers for use in anti-microbial finished fabrics that are able to withstand significant wear and washings and still maintain their effectiveness.

[0064] It is a further object of the present invention to provide an anti-microbial fiber:

combined with color pigments for coloration for the use in anti-microbial finished fabrics to withstand fading;

combined with UV additives to withstand fading and degradation in fabrics exposed to significant UV light;

combined with additives to make the surface of the fiber hydrophilic or hydrophobic;

combined with additives to make the fabric flame retardant or flame resistant;

combined with additives to make the fabric anti-stain; and/or

using pigments with the anti-microbial so that the need for conventional dyeing and disposal of dye materials is avoided.

[0065] These and other objects of the present invention are accomplished by synthetic fibers having anti-microbial and/or anti-fungal properties using various thermoplastic polymers blended with other types of fibers, and additives, some incorporating natural fibers.

[0066] Thus, the present invention provides a synthetic anti-microbial fiber comprising high and low levels of various thermoplastic polymers and controlled concentrations of inorganic anti-microbial additives mixed with polymers and selectively placed in the end product for greatest technical effectiveness and cost effectiveness.

[0067] The anti-microbial and/or other agent(s) are held in the sheath and are exposed externally by suitable sizing of particle cubes and sheath thickness, e.g., using one micron cubes and 2 micron thick sheaths, and similar ratios of sheath to core in other sizes.

[0068] The present invention also provides a synthetic anti-microbial fiber comprising high tenacity polymers e.g. polyesters, polyethylene terephthalate (PET) in one portion and hydrolysis resistance polymers in another portion with hydrophilic and anti-microbial additives. In some applications the latter portion can be deliberately made hydrolysis-vulnerable to allow "blooming" and enhanced access to anti-microbial additives in the course of several washings or extended uses.

[0069] Also, the present invention provides an anti-microbial finished fabric by blending the synthetic anti-microbial fibers with non-anti-microbial fibers such as cotton, wool, polyester, acrylic, nylon, and the like.

[0070] The various polymers, include but are not limited to, polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET), PCT, PETG [PET, type G], Co-PET and copolyesters generally, Styrene, polytrimethylene terephthalate (PTT)m 3GT, Halar®, polyamide 6 or 6,6, etc. The additives include pigments, hydrophilic or hydrophobic additives, anti-odor additives and anti-microbial/anti-fungal inorganic compounds, such as copper, zinc, tin and silver.

[0100] PETG is an amorphous binder fiber which can be blended into yarns with other fibers to form fabrics, as well as non-woven fabrics. After heat activation, the PETG fiber melts, wets the surface of the surrounding fibers, and settles at the crossing points of the fibers, thus forming "a drop of glue" which bonds the fibers together and distributes the anti-microbial additives.

[0101] The excellent wetting characteristics of PETG can be used to distribute the anti-microbial additive uniformly within a yarn or fabric. In addition to the zeolite of silver, the PETG could carry other inorganic anti-microbial additives such as copper, zinc, or tin.

[0102] In addition to the anti-microbial component, the invention may be used to carry pigments with the PETG to achieve certain colors without the need to dye the other fibers.

[0103] The created synthetic fibers of polymers and additives can further be blended with non anti-microbial fibers to provide anti-microbial finished fabrics that are able to withstand significant wear and washings and maintain their effectiveness.

[0104] The use of hot water improves the products in that washing the fibers/products in hot water opens the pores of the PET and such washed products perform better than unwashed products (this is thought to be due to the removal of spinning/weaving lubricants).

[0105] Material can be made in biodegradable form, such as by adding corn starch to the core or sheath polymers. This enables whole families of disposable fibers and fabrics.

[0106] Thus, there still exists a need to develop garments and articles of the type described which are made of fibers having metal-containing anti-microbials that do not cause the development of resistant bacterial strains for incorporation into fibers that are used to make a variety of fabrics. There also still exists a need for these anti-microbial agents to be resistant to being washed away, thus maintaining their potency as an integral part of the garments and articles into which they are incorporated.

[0107] It is a principal object of the air filter embodiment to provide vehicle and aircraft cabin air filter materials that meet these needs in a manner consistent with industry specifications, overall durability, and cost-effectiveness.

[0108] It is another object of the air filter embodiment to provide such filters which are effective to eliminate or at least substantially reduce the "musty air" smell noticed in such cabins.

[0109] The foregoing objects are met by filters based on anti-microbial fibers that have been designed using inorganic silver-containing compounds that allow the formation of both mono- and multi-component polymeric fibers having these anti-microbial agents intermixed within the polymer during fiber formation. The concentration of the anti-microbial agent can be varied within each individual fiber as a gradient using mixing strategies and also from fiber to fiber. The concentration of anti-microbial agent within a fabric or material made from these anti-microbial fibers can also be varied regionally using fibers containing varying amounts of anti-microbial agents in conjunction with both natural and synthetic fibers having different amounts of anti-microbial agents or even no added anti-microbial agents. A variety of other agents can be added, either by mixing or topically, to color the fibers and/or to make it resistant to staining, fire, and ultraviolet (UV) light as well as altering its water absorbing qualities. Various polymers, without limitation, can be used to form these fibers. In the context of this invention, anti-microbial refers, but is not limited, to antibacterial and anti-fungal.

[0110] It is one object of the fabric embodiment to provide a fiber which is used to form a fabric to which qualities may be imparted which last for the life of the fabric.

[0111] It is another object of the fabric embodiment to provide such a fabric which is provided with coloring which remains fast even to sunlight and many launderings.

[0112] It is a further object of the fabric embodiment to provide such a fabric which is provided with a colorant without the use of a dye bath.

[0113] It is still another object of the fabric embodiment to provide a fiber and fabric of the type described which possesses anti-microbial properties.

[0114] It is yet another object of the fabric embodiment to provide a fiber and fabric of the type described in which characteristics may be imparted using agents which become permanently fixed and are maintained for the life of the fabric.

[0115] These objects and others are accomplished in accordance with the present invention which uses PETG:

[0116] As a carrier for pigments for coloration for use in finished fabrics to withstand fading;

[0117] With pigments together with other fibers, so that the need for conventional dyeing and disposal of dye materials is avoided;

[0118] With pigments and other fibers, and the resulting fabric possesses excellent fastness for both sunlight resistance and washing;

[0119] With pigments for coloration, the color of the fabric remains fast for in excess of 50 commercial launderings;

[0120] With pigments blended with cotton, which leaves the encapsulated pigment attached to the outside of the cotton fiber and ceases to be a fiber after activation, so that the resulting fabric can still be labeled 100% cotton fiber; and

[0121] With anti-microbial and/or other additives with any natural fibers, so that the resulting fabrics have anti-microbial and/or other properties with the same characteristics of natural fabrics.

[0122] PETG may be used as one of the polymer blends and/or carriers for a wide variety of applications. PETG is an amorphous binder fiber that can be blended into yarns with other fibers to form woven fabrics, as well as knits and non-woven fabrics. It has two characteristics of particular interest: (1) excellent wetting and (2) low melting temperature (which can be controlled between 90°C and 160°C). It is used in the present invention as a carrier to carry pigments and/or anti-microbial additives and/or other additives and is blended with other fibers which may be natural fibers such as cotton, silk, flax, wool, etc. or other synthetic fibers such as : PET, PP, PE, Nylon, Acrylic, etc. After heat activation, the PETG melts, continuously releases the color pigments and/or anti-microbial or other additives and wets the surface of the surrounding fibers with the pigment and/or anti-microbial or other additives it carries. It settles at the crossing points of the fibers, thus forming "a drop of glue" which bonds the fibers together. Therefore, PETG delivers and distributes the pigments and/or anti-microbial or other additives uniformly within a fabric, generating the finished fabrics and/or fabrics having anti-microbial properties.

[0123] Since the natural fibers used to blend with PETG are not changed physically after heat activation of PETG, they contain the same characteristics as natural fibers. The PETG may be used together with or without anti-microbial agents to form a fabric having excellent color fastness even in the presence of sunlight, and will withstand many washings without deterioration. The fabric is made by blending PETG used as a carrier for pigments and/or anti-microbial additives, with cotton or any other fibers of synthetic material such as from polyester and rayon, and activating PETG from 110° to 140° C. The color is thus provided to the yarn and fabric without the need of going through a dye bath. This fabric remains color- fast for in excess of 50 commercial launderings.

[0124] The excellent wetting characteristics of PETG can be used to distribute the pigments and/or anti-microbial additive uniformly within a yarn or fabric. While many anti-microbial agents may be used, such as those, which use copper, zinc, or tin, the preferred agent is zeolite of silver. In addition to the anti-microbial component and the pigment added to the PETG, the PETG may be used as a carrier to add other properties to yarn and fabric, such as fire retardants.

[0125] The concentration of the anti-microbial agent can be varied within each individual fiber as a gradient using mixing strategies and also from fiber to fiber. The concentration of anti-microbial agent within a fabric or material made from these anti-microbial fibers can also be varied regionally using fibers containing varying amounts of anti-microbial agents in conjunction with both natural and synthetic fibers having different amounts of anti-microbial agents. A variety of other agents can be added, either by mixing or topically, for different reasons, such as altering its water absorbing qualities. Various polymers can be used to form these fibers. In the context of this invention, anti-microbial refers, but is not limited, to anti-bacterial and anti-fungal.

BRIEF DESCRIPTION OF THE DRAWING

[0126] Other objects, features and advantages will be apparent from the following detailed description of preferred embodiments taken in conjunction with the accompanying drawings in which:

- [0127] **FIGS. 1A, 1B, 1B', 1B'' and 1C** are cross-sectional views of various fiber configurations used in practice of the various embodiments of the invention;
- [0128] **FIG. 2** is a sketch of a fibrous mass using one or more of the fibers of **FIGS. 1A-1C**;
- [0129] **FIG. 3** is a schematic view of the feed hopper, screw and extruder;
- [0130] **FIG. 4** is a sectional view through the exit of the extruder showing the formation of coaxial bi-component fibers of the present invention;
- [0131] **FIGS. 5 and 6** are photomicrographs of fibers showing the particles of zeolite of silver;
- [0132] **FIG. 7** is a cross section of one type of filter using the fibers of the present invention;
- [0133] **FIGS. 8A, 8B, 8C, 8D** are diagrams of air flow systems utilizing the fibers of the invention;
- [0134] **FIG. 9** is a flow chart showing the preparation of the fibers and yarn for use in making a woven or nonwoven fabric;
- [0135] **FIG. 10** is a flow chart showing the preparation of fibers and yarn and then of a fabric;
- [0136] **FIG. 11** is a flow chart showing another manner of preparing fibers in accordance with the present invention;
- [0137] **FIG. 12** is a schematic view of a humidifier evaporation surface media used to humidify air;
- [0138] **FIG. 13** is a schematic view of a humidifier pad or filter in a system; and
- [0139] **FIG. 14** is a pad or filter for a circulation/aeration system.

DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

[0140] In the United States, all claims concerning anti-microbial and anti-fungal properties must be thoroughly tested to Environmental Protection Agency (EPA) and Food and Drug Administration (FDA) standards before making claims. The anti-microbial herein can be said to "kill bacteria" in that it kills 99.99% (log 4) of bacteria in 24 hours, and "anti-microbial" in that is

kills 99.9% (log 3) of bacteria in 24 hours. This is based upon actual test results. Testing, such as by using the shake flask test, has demonstrated that when fibers and fabrics are tested using the anti-microbial system disclosed herein, the number of bacteria on the fibers is reduced by 99.99% or more over a 24-hour period and at least by 99.9%. This testing was performed using several different bacteria, including *Pseudomonas aeruginosa*, *Staphylococcus aureus* and *Klebsiella pneumoniae*. The testing was conducted using both unwashed fibers and fibers that had been washed fifty times to simulate use of the fiber in an application, such as a pillow. The EPA has indicated that products tested using this system may claim "Prohibits Bacteria Growth and Migration Along the Surface of the Product." The addition of the agent in this system inhibits the growth of mold and mildew or odor-causing bacteria in the fibers. This is a true anti-microbial product. The fibers retain their efficacy after simulated use conditions so that the anti-microbial action lasts the life of the product.

[0141] *THE FIBERS AND THE ADDITIVES*

[0142] According to a first configuration of the present invention shown in **FIGS. 1A-2** a bi-component fiber **10A** is formed of a sheath component S and a core component C using polyethylene terephthalate (PET) (or other thermoplastic polymer) in the core, making up between 20 to 80 % of the fiber by weight. The sheath is also PET, or other thermoplastic polymer, making up between 80 to 20% of the fiber by weight including, as a dispersed solid, additive A (or compounded with the sheath plastic) an anti-microbial compound, to gain the efficiency of the additive on the surface and not wasting the additive in the core.

[0143] In the more generalized case as mentioned above, the sheath may be quite thin. However, preferably the sheath is more than 28% of the total fiber cross-section. It has been found that one of the best methods for retaining the anti-microbial qualities in the fiber and in fabrics is to use sheath thicknesses which are properly related to the size of the anti-microbial additive particles. For example, when the anti-microbial particles are approximately 1 micron cubes, which provides diagonal dimensions of approximately 1.7 microns, the sheath thickness would be in the vicinity of 2 microns. In this manner the particles of the agent are firmly held in

the sheath by the material of the sheath holding them in place. When the particles are larger or smaller, the thickness of the sheath is adjusted accordingly.

[0144] The anti-microbial/anti-fungal additives are inorganic compounds using such metals as: copper, zinc, tin, and silver. The best results are obtained using a zeolite of silver dispersed in a polyethylene (PE), PET, or polybutylene terephthalate (PBT) carrier, but could be added directly to a melt of a sheath thermoplastic without an intermediate carrier. The total anti-microbial additive ranges from 0.2% (0.002) to 6.0% (0.06) by weight of fiber depending on performance requirements. The anti-microbial additives are held in the sheath and are prevented from washing off over time and remain effective, especially when the sheath-thickness to agent-particle size ratio is in a desirable range as mentioned above and discussed in more detail below.

[0145] The bi-component anti-microbial/anti-fungal synthetic fiber size would preferably range from 0.7 dTex to 25.0 dTex and could be produced as a cut staple fiber in lengths from 1.0 mm to 180 mm, or in a continuous filament.

[0146] Additives which can be incorporated include one or more of UV stabilizers at 0.1% (all %'s herein are by weight unless otherwise stated) to 5.0%; fire retardant (FR) additives at 0.1% to 5.0%; pigments at 0.1% to 6.0%; hydrophilic additives at 0.2% to 5.0%; hydrophobic additives at 0.2% to 5.0%; and/or anti-stain additives at 0.2% to 5.0%.

[0147] A second configuration of this first embodiment of the present invention is a bi-component fiber **10B** in which the components x, y (x = strength, y = functional portion) are side-by-side and the same polymers and additives are used as described above. Variants of this are shown in **FIG. 1B'** in which the tri-component fiber **10B'** has components x1, x2 and y', and in **FIG. 1B''** in which the four-component fiber **10B''** has components x1, x2, y1 and y2.

[0148] A third configuration shown in **FIG. 1C** is a continuous filament **10C** that could be used by itself as the binder or as part of a yarn or fabric with cooperating (strength) fibers indicated at **10D**.

[0149] It should be understood that the nominal "binder" fiber or binder component can also be a strength enhancer in some combinations. It will also be understood that other variants with respect to **FIGS. 1A-1C**, including, but not limited to combinations, can be made. For example, a

first extrusion could produce intermediate fiber products as in **FIG. 1A** and such products could be put together with each other or separate strength fibers and processed to produce simulations of **FIGS. 1B, 1B', 1B'', 1C**.

[0150] **FIG. 2** shows a non-woven or woven fibrous mass M made up of any of the fibrous configurations of **FIGS. 1A-1C** after heating wherein the binder fiber component melts and flows to form locking knots at many (if not most or all) of the cross-over points or nodes N of the fibrous mass to enhance strength and durability of the mass while maintaining a dispersion of the binder materials and its functional additive(s).

[0151] While the preferred embodiment is a PET/PET bi-component with zeolite of silver being used only in the sheath. Resins with different viscosities can be used to obtain improved performance. A PCT/PET arrangement is one variation which takes advantage of the hydrolysis resistance and resilience; however, the PET/PET is more cost effective, especially for use in apparel and bedding.

[0152] **FIGS. 1A-2** can also be used to describe a second embodiment grouping of practice of the invention.

[0153] The first configuration of the second embodiment of the present invention is a bi-component fiber of a core and a sheath as shown in **FIG. 1A** using PET or other high tenacity polymer in the core at between 20% and 80% by weight of the fiber. Poly 1,4 cyclohexylene dimethylene terephthalate (PCT) or other hydrolysis resistant polymer is used for the sheath at 80% to 20%. The core is designed to provide the strength of the fiber and the modulus can be varied to create a high modulus fiber with properties of high tenacity and low elongation similar to cotton, or a low tenacity and higher elongation fiber with properties similar to wool; or anywhere in between to obtain different fibers to make them as compatible as possible for their end uses and for any blend in which they will be used. In fibers, modulus refers to the area under the curve in a stress/strain curve. The sheath is preferably over 28% of the total cross sectional area. The sheath uses PCT which provides a hydrolysis resistant surface with good wrinkle resistance and resistance to long term washings in boiling water and strong soaps.

[0154] Additives in this second embodiment include pigments, compounds to create a hydrophilic surface, and anti-microbial, anti-fungal, anti-odor additives. The pigment additives are to provide uniform colors that do not fade significantly over long-term use and washing, unlike dyes. Compounds may be used which create a hydrophilic surface and this is designed to wick body moisture away from the skin and evaporate to create comfort for a wearer of a garment containing such fibers and is particularly useful for career apparel such as uniforms, work clothes, etc. The anti-microbial, anti-fungus and anti-odor additives can be varied depending on the functionality of the career apparel.

[0155] The bi-component anti-microbial/anti-fungal synthetic fiber size ranges from 0.7 dTex to 25.0 dTex and can be produced as a cut staple fiber in lengths from 1.0 mm to 180 mm, or in a continuous filament.

[0156] Another arrangement (**FIG. 1C**) is a bi-component continuous filament that could be used by itself or as part of a yarn or fabric.

[0157] **FIGS. 1A-2** can also be used to describe a third embodiment grouping of practice of the invention.

[0158] The third embodiment of the invention is a mono-component of homo-polymer fiber made from low temperature polymers with a melting or softening temperature below 225° C. such as PETG. It relates to a binder fiber carrier for anti-microbial additives, which can be further blended with non-anti-microbial fibers to provide an anti-microbial finished fabric that is able to withstand significant wear and washings and maintain their effectiveness. The anti-microbial additives are inorganic.

[0159] A mono-component or homo-polymer fiber used in this embodiment was made from low temperature polymers with a melting or softening temperature below 225° C. such as PETG (PET modified with 1,4, cyclohexanedimethanol), PE, PP, co-PET, or amorphous PET. Another low melting temperature polymer which may be used is polycaprolactam (PCL). The anti-microbial additives are inorganic compounds made from metals such as copper, tin, zinc, silver, etc. The preferred compound is a zeolite of silver dispersed in PE, PET, or PBT before being added to the fiber. The additives could be added directly to the primary polymer with pre-

dispersion. The total active ingredients range from 0.1 to 20% by fiber weight. Other inorganic metals such as tin, copper, zinc, etc. work also but not as well as zeolite of silver.

[0160] The binder (carrier) fiber containing polymers and anti-microbial additives can be blended with non anti-microbial natural fibers such as cotton and wool, or synthetic fibers such as polyester, acrylic, nylon, PTT, 3GT, rayon, modified rayon, and acetate to an anti-microbial finished fabrics that is able to withstand significant wear and washings and maintain their effectiveness.

[0161] A typical example is a fiber using the PETG polymer with the zeolitic contained silver additive blended with cotton up to 10% by weight to produce a bed sheet. The binder fiber is activated in the drying cycle of the final bleaching operation or other heat operation. The PETG melts and wets the surface of the cotton fibers to carry the anti-microbial characteristics to the entire sheet with an added benefit of increasing strength and reducing pilling.

[0162] The fiber size ranges from 0.7 dTex to 25 dTex and a staple length of 1.0 mm to 180 mm. A continuous filament yarn can also be produced that can be used in a wrap spun application whereby non-anti-microbial fibers are spun around the anti-microbial filament.

[0163] The antimicrobial product withstands more than 50 commercial washings at 80° C and/or dry cleanings. It is immune to UV exposure of at least 225 kj. It possesses excellent abrasion resistance and is unaffected by tests such as Tabor or Wyzenbeek.

[0164] The present invention also provides a unique way to use polymers such as PETG to carry and deliver anti-microbial additives and/or pigments to a natural non-anti-microbial fiber, such as cotton, wool, possibly mixed with polyester, nylon and the like, and generate a final binding fabric having anti-microbial properties.

[0165] PETG has two characteristics of interest: (1) excellent wetting and (2) low melting temperature. In the present invention, it is used as a carrier to carry anti-microbial additives and be blended with non-anti-microbial fibers. After heat activation, the PETG melts, continuously releases the anti-microbial additives and wets the surface of the surrounding non anti-microbial fibers with the anti-microbial additives it carries. Thus, PETG delivers and distributes the anti-microbial additive uniformly within a fabric and the PETG holds the anti-microbial agent in

place, generating the finished fabrics having anti-microbial property. Since the natural fibers used to blend with PETG are not changed physically in this process, they contain the same characteristics as natural fibers.

[0166] The bi-component fiber may be formed by the use of pellets of the two different polymers or a direct polymer stream from the reactor of which the fiber is to be formed. The arrangement shown in **FIG. 1A** is intended for a configuration of a core fiber, and a sheath fiber which contains an additive, e.g., an anti-microbial agent. Since the best of the anti-microbial agents known at this time to the present inventor is zeolite of silver, the present example uses this agent. The intent is to use the minimum amount necessary to provide the desired characteristics. The additive provides the desired anti-microbial effect only at the surface. Therefore, if the bulk of the additive is located within the volume of the fiber well below the surface, that portion will not be useful for most or all of the life of the material into which the fiber is made. Since there frequently is some surface abrasion, some of the additive particles which are just below the surface when the fiber is made, become available at the surface, later in the life of the product.

[0167] In the past, attempts have been made to provide the additive at the surface, and the result was that the additive particles did not have a very useful life since they were removed from the surface by washing and wear or use. Therefore, the present invention strongly attaches the additive particles to the outer region of the fiber.

[0168] It has been possible to make particles of zeolite of silver as small as 1 micron cubes. A particle of such size will have a diagonal dimension of about 1.7 micron. Therefore, the smallest thickness of the sheath would be about 2 microns. The present invention permits a core/sheath arrangement in which the sheath is as small as 2 microns in thickness with the additive incorporated into the sheath. The diameter of the sheath is adjusted to the particle size so that the particles are held firmly in place and are available at the surface of the sheath. The particles may be smaller or larger than 1 micron cubes or larger, and the sheath may be correspondingly smaller than 2 microns or larger. In such an arrangement most, or all, of the additive is available for surface action, and, with wear and/or washings a small amount of the surface of the sheath will wear or wash away, and other additive particles which were originally more deeply embedded, become available at the surface.

[0169] The photomicrographs of **FIGS. 5 and 6** show the small particles of zeolite of silver in the sheath, many of which can be seen on the surface or projecting through to the surface of the fibers. There are more such particles which are just below the surface of the fibers, and which will become available for anti-microbial activity as small portions of the fiber wears or washes away and the particles become available at the surface.

[0170] **FIGS. 3 and 4** show a manner of making a core/sheath fiber with an anti-microbial additive which is incorporated into the sheath polymer prior to the final extruding of the fiber. In the prior art, this was mostly done as a treatment after extruding.

[0171] The extruder **12** is shown diagrammatically in **FIG. 3** having a feed hopper **14**, an extruder screw section **16** for feeding melted material to the delivery end, and a heating chamber **18** which surrounds the bottom of the feed hopper as well as the total length of the extruder screw section **16** for melting the pellets which are fed into the hopper and maintaining the polymers in melted condition for being extruding through the extruding openings which act as nozzles. Besides pellets, it is possible to make these fibers using direct polymer streams from continuous reactors feeding to the melt pumps for a company which is a polymer producer.

[0172] There are two extruders, one which has a feed hopper for forming the sheath and another with a hopper for forming the core.

[0173] The nozzle end of the extruder is shown in cross section in **FIG. 4** which includes three sheets of metal **20, 22 and 24** to form two chambers **26 and 28**. The melted polymer is fed into the extruder nozzle from the top. There are a plurality of two types of holes, one type being **28** and which feeds into chamber **26** to form the core of the fiber, and the other type being **32** which feeds into chamber **28** to form the sheath of the fiber.

[0174] The following non-limiting examples illustrate practice of the invention.

Example 1

[0175] The anti-microbial fiber of the present invention was used in the making of a mattress pad. In this example, 15% of a 6.7 denier 76mm cut length natural white fiber was used as a homofilament with zeolite of silver as the anti-microbial agent and 15 % of a bi-component fiber

was used together with 70% PET 6x3 T295 in a blend in which the zeolite of silver comprised 0.9% of the fiber. The blend of this fiber was made into a batt of about 1-1 1/2 " thickness of nonwoven material which was then placed between two layers of woven fabric to form a mattress pad. When tested using the shake flask test this provided a 99.99% microbial kill ratio.

[0176] There are other examples in which all of the parameters of Example 1 were used and in each of which there was 15% of a bi-component fiber used. Again the zeolite of silver comprised 0.9% of the fiber. The percentage of the anti-microbial fiber ranged from 20% to 40% and the PET ranged from 45% to 65%. In all examples the microbial kill ratio was 99.99% using the shake flask test.

Example 1A

[0177] In this example, 35 % of a 6.7 denier 51mm cut length natural white fiber was used in a sheath/core bi-component configuration with zeolite of silver as the anti-microbial agent and 15% of another bi-component fiber was used together with 50% PET 6x3 T295 in a blend in which the zeolite of silver comprised 1.8% of the fiber. The blend was then prepared as in Example 1 and when tested using the shake flask test, there was a 99.9% microbial kill ratio.

[0178] A second group similar to the first one was prepared in which the sheath/core bi-component fiber with zeolite of silver as the anti-microbial agent comprised from 10 to 35% of the fiber blend, 15% of another bi-component fiber was used and from 50 to 75% of PET 6x3 T295 was used. The zeolite of silver comprised 0.75% of the fiber. In the shake flask test, there was a 99.99% microbial kill ratio.

Example 2

[0179] In this example, 15% of a 3.5 denier 38mm cut length PETG fiber was used as a homofilament with zeolite of silver as the anti-microbial agent. 85% PET fiber was blended with the PETG anti-microbial fiber to form a blend in which the zeolite of silver comprised 1.8% of the fiber. The fiber was made into a wall covering and was tested by the shake flask test, which provided a microbial kill rate of 99.99%

[0180] A modified version was prepared the same way except that there was only 10% fiber with zeolite of silver in the blend and 90% PET fiber was used. After the fiber was made into a wall covering, this too provided a 99.99% microbial kill rate using the shake flask method of testing.

[0181] A further modified version was used in which there was only 5% fiber having zeolite of silver in the blend and 95% PET fiber in the blend. The testing, after the fiber was used in a wall covering, again provided a 99.99% microbial kill rate for bacteria.

[0182] The fibers described above can be used to make both woven and nonwoven fabrics as well as knitted fabrics. Such fabrics are useful for various types of articles, some of which are listed below.

AIR FILTERS

[0183] Air filters for HVAC systems, air conditioning systems, car and airplane cabin systems as disclosed, for example, in Serial No. 60/172,285 filed December 17, 1999, the contents of which are incorporated herein below, in which filters and filter materials are made of anti-microbial fibers for a variety of filter applications in which it is necessary or desirable to reduce bacterial and fungal growth and their resultant odor. Specifically, in vehicles, such as automobiles, the air filters and attached air conditioning units are the source of musty smells associated with the seeding and growth of bacteria, fungi, mold, and mildew. Because of the recirculation of outside and air-conditioned air through these filters, very favorable conditions exist for the growth of bacteria, fungi, and other microbes. Also in aircraft cabins, the air filters have the same beneficial results. An anti-microbial filter is made of fiber, which comprises various thermoplastic polymers and additives in a mono-component or bi-component form in either a core-sheath or side-by-side configurations. The anti-microbial synthetic fibers can comprise inorganic anti-microbial additives, distributed only in certain areas in order to reduce the amount of the anti-microbial agents being used, and therefore the cost of such fibers. The anti-microbial additives used in the synthetic fibers do not wash off over time because they are integrally incorporated into these fibers, thus their effectiveness is increased and prolonged. The anti-microbial synthetic fibers comprise high tenacity polymers (e.g. PET) in one component and

hydrolysis resistance polymers (e.g. PCT) in another component. The hydrophilic and anti-microbial additives provide a hydrolysis-resistant surface. The anti-microbial synthetic fibers can further be blended with non-anti-microbial fibers such as cotton, wool, polyester, acrylic, nylon etc. to provide anti-microbial finished filters that are able to withstand significant wear and washings and while maintaining their effectiveness.

[0184] The present invention provides filters based on anti-microbial fibers that have been designed using inorganic silver-containing compounds that allow the formation of both mono- and multi-component polymeric fibers having these anti-microbial agents intermixed within the polymer during fiber formation. The concentration of the anti-microbial agent can be varied within each individual fiber as a gradient using mixing strategies and also from fiber to fiber. The concentration of anti-microbial agent within a fabric or material made from these anti-microbial fibers can also be varied regionally using fibers containing varying amounts of anti-microbial agents in conjunction with both natural and synthetic fibers having different amounts of anti-microbial agents or even no added anti-microbial agents. A variety of other agents can be added, either by mixing or topically, to color the fibers and/or to make it resistant to staining, fire, and ultraviolet (UV) light as well as altering its water absorbing qualities. Various polymers, without limitation, can be used to form these fibers. In the context of this invention, anti-microbial refers, but is not limited, to antibacterial and anti-fungal.

[0185] The amount of time people spend in their vehicles has been increasing over the last 20 years. The passenger compartment of these vehicles is an extension of people's personal space. The desired quality of the air in that space increasingly reflects peoples' desire to be protected from airborne particles and odors, and bacteria. Such vehicles include pick-up trucks, SUVs, recreational vehicles, buses, over-the-road trucks, and the like.

[0186] Anti-microbial fibers can be used to make filter materials for a variety of applications in which it is necessary or desirable to reduce bacterial and fungal growth and their resultant odor.

[0187] Specifically, the built in or attached air conditioning units for over the road vehicles are a source of musty smells associated with the seeding and growth of bacteria, fungi, mold, and mildew on the evaporator and or heater cores and housings. These areas, by their nature, collect

dust, dirt, bacteria, mold spores, etc. in an environment that contains the moisture, temperature, and shielding from direct sunlight necessary to promote growth of these organisms.

[0188] A filter containing permanent anti-microbial fibers, described herein, could be placed in the outside make-up air and /or recirculated air streams to kill the spores and cells trapped by the filter. This would reduce or eliminate the odors associated with growing and reproducing organism.

[0189] The permanent nature of the anti-microbial fibers in the filter is necessary based on the environment of operation and desired replacement life. The filters are subjected to moisture from entrained water from the blower fan inlet (rain, or wash water) as well as condensation of moisture when the air conditioning system is in operation. Further, the vehicle owners, and vehicle design engineers, want a filter that has at least a one year life. Both conditions can be overcome with permanently anti-microbial fibers described herein.

[0190] Such anti-microbial fiber-containing filters are useful in reducing the build-up of biological materials and films on the filters themselves and the associated air conditioning units. Thus, they would also be less likely to impart undesirable odors to the interior of the vehicles.

[0191] In manufacturing these materials, any of the embodiments described above could be used. Both the strength and resiliency of these materials is important given that they are used in continuously circulating air streams and are subject to the pressures characteristic of filtering processes. Any number of filter shape designs could be used as appropriate. In some instances, round filters would be appropriate whereas in other instances pleated or other shape filters would be appropriate, all depending on the pressure, volume characteristics of the air flow and available space. Thus, both bi-component fibers and mixed fiber fabrics are useful embodiments for vehicle and aircraft cabin air filters. Also, other modifications of the characteristics of these fibers and fabrics beyond that of adding anti-microbial agents, including the addition of agents to increase or decrease hydrophobicity, would be useful. In addition, anti-odor additives may be particularly useful in this application given the use in connection with air conditioners.

[0192] Thus, these anti-microbial materials that are manufactured to be used in vehicle and aircraft cabin air filters will then significantly reduce the growth of mold, mildew, and bacteria.

By achieving this goal, odors associated with the long-term use of these filter materials will be reduced. This will also then result in a significant costs savings in the operation of air recirculation systems in automobiles.

[0193] Filters for vehicle and aircraft cabins are, according to the invention, made of anti-microbial fibers which use inorganic silver-containing compounds that are integrated into the polymers that are used to make these anti-microbial fibers. Such a filter is shown diagrammatically in **FIG. 7**. The example shown is a typical progressive filter which has three layers. There is a support layer **44**, then a filtration layer **42** made with anti-microbial fibers and then a prefilter layer **40** also made with anti-microbial fibers.

[0194] The relatively small size of the silver-containing zeolite compounds (2 microns and less) that are used in the manufacturing of the fibers allow these anti-microbial agents to be incorporated into fibers instead of being applied to them. For example, a bi-component fiber is made with the sheath having a thickness which is properly related to the cubic size of the zeolite particles. Zeolite particles having a one micron cube size would be placed into a sheath having a two micron thickness. Thus, because these anti-microbial agents are an integral part of the fiber, they are not washed or easily abraded away and the finished articles, in the present case, filters, manufactured from them are able to withstand significant wear and multiple washings while maintaining their anti-microbial effectiveness (for those filters which are washed). In the case of filters which are thrown away when they start to become clogged with filtered material (air borne particles and the like) the resistance to washings is not an important factor.

[0195] **FIG. 8A** shows a system of filter usage for an occupancy zone where air is removed via valve V1 through a pump or compressor P passed through a filter canister F (or other container) and a heating or cooling exchanger (HVAC) and returned to the occupancy zone via valve V2. The system can also handle outside air via a valve V3.

[0196] The canister has a removable anti-microbial filter screen F (with a frame, not shown) removable for exchange or regeneration of anti-microbial effectiveness from time to time.

[0197] Another form of filter is shown in **FIG. 8B** as filter canister FC' with vanes V defining a tortuous path, the vanes being lined with anti-microbial screening material F'

[0198] **FIG. 8C** shows another form of canister as a tube FC" lined with such filter material F" and **FIG. 8D** shows a canister FC'" with a loose array of filter material F'" (similar to a scouring pad).

FABRIC

[0199] Fiber and fabric which are color-fast and which can be for pastel shade fabric, as disclosed, for example, in Serial No. 60/180,536 filed February 7, 2000, the contents of which are physically incorporated herein below, in which PETG which is an amorphous binder fiber is used and is blended into yarns with other fibers to form fabrics, as well as knits and non-woven fabrics. After heat activation, the PETG fiber melts, wets the surface of the surrounding fibers, and settles at the crossing points of the fibers, thus forming "a drop of glue" which bonds the fibers together. PETG is also used to carry pigments and/or anti-microbial additives to the fibers, distribute the pigment and/or anti-microbial additives on the surface of the surrounding fibers, and achieve certain colors without the need to dye the fibers and natural fabrics having anti-microbial qualities. This invention presents a method for making a pastel shade fabric and/or nature fabrics having anti-microbial activities by using PETG as a carrier for pigments and anti-microbial additives, blending them with cotton or any other fibers, activating and melting PETG from 110° to 140°C., and leaving the encapsulated pigment and anti-microbial additives on the fibers. The final pastel shade fabric having an excellent fastness for both sunlight resistance and washing without the need of going through a dye bath, and has the color remain fast for in excess of 100 commercial launderings. If the pastel shade fabric is made by blending PETG and pigments with cotton, after the activation of PETG, the final product can still be labeled as 100% cotton fibers. Thus, the present invention provides a fiber, yarn and/or fabric construction. There is a method for making a fiber blend which includes mixing a polyester polymer, characterized by a low melting temperature and having binder qualities, with an additive for providing desired characteristics to a finished fiber. The mixture is heated and extruded to form a continuous filament. The continuous filament fiber is cut to form a cut filament fiber. The cut filament fiber is blended with a natural fiber to form a fiber blend. The fiber blend is heated to a temperature in the melting temperature range of said polyester polymer for a sufficient period of time to melt the

low melting temperature polyester polymer and wet the natural fiber and provide such natural fiber with the additive firmly attached thereto. The polyester polymer may be PETG. After the fiber is prepared it may be spun to make a yarn and the yarn may be made into a fabric. The heating step can take place after the yarn is made into a fabric. The additive may be a colorant, an anti-microbial agent, a fire retarding agent, or another agent which adds properties to the fiber or yarn or fabric. There is another method for making a fiber, which includes mixing a polyester polymer, characterized by a low melting temperature and having binder qualities, with an additive for providing desired characteristics to a finished fiber, heating the mixture and extruding it to form a continuous filament. Another polymer is heated and extruded to form a continuous filament. The extruding steps form a bi-component fiber with the mixture forming the sheath and the other polymer forming the core. The sheath is heated to a temperature in the melting temperature range of the polyester polymer for a sufficient period of time to melt the low melting temperature polyester polymer and wet the core fiber and provide the core fiber with the additive firmly attached thereto.

[0200] The fabric invention provides a unique way to use polymers such as PETG to carry and deliver pigments and/or anti-microbial or other additives to a natural fiber, such as cotton, wool, and the like, and generate a final pastel shade fabric without losing the natural fiber's characteristics and/or natural fabric having anti-microbial properties.

[0201] PETG is used as a carrier for pigments, such as carbon black, phthalo blue, and the like. It is mixed with other fibers, such as natural fibers, to form a blend, and then the blend is heated, to a temperature of around 140° C. (the PETG can be modified to melt between 90 and 160°C) either as a separate heating step or during a processing step which includes heating to about temperature. PETG has a melting temperature of around 140° C (and is available from 90 to 160°C.) and it melts and flows along the fibers with which it is blended. It acts as a binder-carrier in that it forms nodes of color (when a colorant is used) with many points so it looks like a solid color. This provides it with a pastel look. By controlling the amount of colorant added to the PETG there is controllable color values which include pastel shading. PETG has superior wetting ability and therefore it spreads evenly along the other fibers with which it is blended. There are also nodes formed at the intersecting fibers in the blend and there are held together by

this characteristic of the PETG. Also, the amount of PETG can be controlled to be small quantities with respect to the other fibers in the blend. Thus, when blended with cotton in this manner, such a blend may properly be characterized as "all cotton" having color and/or anti-microbial (or other) agents, which have been added by the PETG.

[0202] This can be accomplished in more than one manner. One method is shown in **FIG. 9** in which the PETG and colorant pellets are mixed together, after which they are heated to melt and are then extruded to form a PETG fiber with the colorant in it. The PETG is then blended with a natural fiber, such as cotton, to form a blend, which will have the color of the colorant, which the PETG fiber takes on as its color. The cotton is white so that the color taken on is a pastel color. If the colorant is black, then the blend becomes a shade of gray. If desired other fibers can be blended with the PETG fibers, such as silk, flax, polypropylene, polyethylene, wool, polyester, acrylic, nylon, PTT, 3GT, rayon, modified rayon, and acetate.

[0203] The PETG is then activated by heating it as a temperature of from about 110° to about 140°. This melts the PETG without harming the fibers with which it has been blended. The PETG carrier melts and wicks along the other fibers, that is the cotton or other base fibers, forming small nodes, but it does not ball up as some polymers do and provides "a drop of glue" (small) to bind the fibers together and leaves behind the encapsulated pigment in the fibers.

[0204] This fiber blend is then used to form a yarn with in turn is used to form a fabric. The resulting fabric is a pastel shade fabric without the need of going through a dye bath, and has excellent color fastness from both sunlight and washing. The color is a pastel since there are many tiny drops of the colorant which looks like a solid color to an observer. The color remains fast for in excess of 100 commercial launderings. Since the PETG carrier melted after activation, the blended fibers such as cotton are still considered to be 100% cotton fiber.

[0205] **FIG. 10** shows a method similar to that shown in **FIG. 9**. However, in this process the blended fiber is made into a yarn and the yarn is made into a fabric before the PETG is activated by heating. This heating may be a separate heating step or may take place during the processing of the fabric which may include a heating step for other reasons.

[0206] The present invention may also be used to provide anti-microbial fibers by using PETG as a carrier for anti-microbial additives. Again the PETG and the anti-microbial pellets may be melted together to form a melt which is extruded to create a continuous filament which is then cut to appropriate size and is then further blended with natural or other fibers to provide an anti-microbial finished yarn which may be made into an anti-microbial fabric that is able to withstand significant wear and washings and maintain their effectiveness. The anti-microbial additives are inorganic compounds made from metals such as copper, tin, zinc, silver, and the like. The preferred compound is a zeolite of silver which may be dispersed in PE, PET, or PBT before being added to the fiber. The additives can be added directly to the primary polymer with pre-dispersion. The total active ingredients range from 0.1 to 20% by fiber weight. Other inorganic metals such as tin, copper and zinc work also, but not as well as zeolite of silver.

[0207] The PETG polymers with anti-microbial additives can be blended with natural fibers such as cotton, silk, flax, and wool, or synthetic fibers such as polyester, polypropylene, polyethylene, acrylic, nylon, PTT, 3GT, rayon, modified rayon, and acetate to make anti-microbial finished fabrics that are able to withstand significant wear and washings and maintain their effectiveness.

[0208] A typical example is a fiber using the PETG polymer with the zeolite contained silver additive blended with cotton up to 10% by weight to produce a bed sheet. The binder fiber is activated during the drying cycle of the final bleaching operation or other heat operation. The PETG melts and wets the surface of the cotton fibers to carry the anti-microbial characteristics to the entire sheet with an added benefit of increasing strength and reducing pilling.

[0209] The fiber size ranges from 0.7 dTex to 25 dTex and a staple length of 1.0 mm to 180 mm. A continuous filament yarn can also be produced that can be used in a wrap spun application whereby fibers are spun around the anti-microbial filament.

[0210] The anti-microbial product withstands more than 50 commercial washings at 80° C. It is immune to UV exposure of at least 225 kj. It possesses excellent abrasion resistance and is unaffected by tests such as Tabor or Wyzenbeek. It is not affected by at least 50 dry cleanings.

[0211] FIG. 11 is another flow diagram for an arrangement, which provides a bi-component fiber with a PET core and a PETG sheath containing a desired additive, such as pigment and/or an anti-microbial agent. The PETG and the colorant pellets are placed into a first extruder and PET pellets are placed into a second extruder. Both are heated sufficiently so that the extruders cause the melts to flow to a single spinneret in which the PET is made into the core and the PETG is made into the sheath. In the fiber state, or in a more finished yarn state, or in an even further finished woven or nonwoven fabric state, the fibers are subjected to heat in the vicinity of 140° C. which melts the PETG without harming the PET which has a higher melting point. This heating step provides the benefits of the present invention as discussed above.

CAR WASH MATERIALS

[0212] Car wash materials, including shami type materials, in which the anti-microbial features last for the normal life of car wash cloths, for example, from 6 to 9 months. In car washes, many types of fabrics are used in the washing process. For instance, the automatic machines that wash cars use a variety of shaped fabrics to clean the car. In addition, cloths of various kinds are used in the waxing, drying, and finishing processes. Due to their continual contact with water, which itself is often recycled, these materials are often wet for long periods of time. This type of situation is very favorable to the growth of bacteria, fungi, and other microbes. As a result of the above, the use of anti-microbial fibers in the manufacture of materials used to clean cars in car washes is a desirable goal. These anti-microbial fiber-containing materials are useful in materials used by the automatic machinery and by individuals employed to clean the cars as well as in other ancillary materials. Specifically, the shaped fabrics used for automatically cleaning the car and the hand towels used to wax, dry, and otherwise finish the car are better products when these anti-microbial fibers are added to them. In manufacturing these materials, any of the embodiments described above could be used. Both the strength and resiliency of these materials is important given that they are used multiple times and are subject to being constantly in contact with water. Thus, both bi-component fibers and mixed fiber fabrics are useful embodiments for car wash materials. Also, other modifications of the characteristics of these fibers and fabrics beyond that of adding anti-microbial agents, including the addition of agents to

change the hydrophobicity, are useful in view of their constant contact with water. Thus, these anti-microbial materials that are manufactured to be used in car washes significantly reduce the growth of mold, mildew, and bacteria. By achieving this goal, odors associated with the long-term use of these materials is reduced. Also, the number of times they can be re-used before being discarded is increased, both because of the incorporation of anti-microbial fibers into these materials and the strengthening strategies indicated above. These characteristics also result in a significant costs savings in the operation of car washes. The hydrophilic and anti-microbial additives provide a hydrolysis-resistant surface that results in long-term protection against washings in boiling water and strong soaps, and also degreasers and chemical based cleaners. The anti-microbial synthetic fibers can further be blended with non-anti-microbial fibers such as cotton, wool, polyester, polypropylene, acrylic, nylon and the like, to provide anti-microbial finished fabrics that are able to withstand significant wear and washings and while maintaining their effectiveness;

CAR WASH WATER FILTERS

[0213] Car wash water filters are more useful when the anti-microbial fibers are used in the making of such filters. Also batts and "brillo" type pads can be used which float, or are submerged in a recycled water storage tank, and the anti-microbial fibers included in them kill the microbes, which are in the tank. This is especially important in car washes, which recycle the wash water, which is the majority of car washes. In car washes, the water that is used to wash the cars and the associated materials for performing the washing and drying operations is often recycled water. However, there are several disadvantages to using recycled water. These include the dirt and odor-causing materials found in the water, including various bacteria, fungi, and other microbes. Because of the use of recycled water, very favorable conditions exist for the growth of bacteria, fungi, and other microbes. As a result of the above, the use of anti-microbial fibers in the manufacture of filter materials used to clean the recycled water before re-use in car washes is a desirable goal. These anti-microbial fiber-containing filters are useful in reducing the build-up of biological materials and films, both on the machinery employed to clean fabrics and other materials associated with the car wash process, due to the recycled water re-use. Specifically, the

shaped fabrics used for automatically cleaning the car and the hand towels used to wax, dry, and otherwise finish the car are less prone to the development of bacterial and fungal films. They are also less likely to impart undesirable odors to the car itself. In addition, the recycled water itself would be less likely to impart any odors to the car. They assist in improving the air quality for customers as they drive through a car wash, and also for the employees. In manufacturing these materials, any of the embodiments described above could be used. Both the strength and resiliency of these materials is important given that they are used multiple times and are subject to the high pressures characteristic of filtering processes. Any number of filter shape designs could be used as appropriate to the step in the filtration that was being performed. In some instances, round filters would be appropriate whereas in other instances pleated or other shape filters would be appropriate, all depending on the pressure and volume characteristics of the recycled water flow. Also, the batts mentioned above can be used in the recycled water storage tanks or sumps to assist in cleaning the water by killing microbes and fungi. Anti-odor additives may be particularly useful in this application given the use of recycled water. Thus, these anti-microbial car wash filters and batts significantly reduce the growth of mold, mildew, and bacteria in the recycled water and on car wash materials. By achieving this goal, odors associated with the long-term use of recycled water and these materials would be reduced. Also, the number of times the recycled water and the car wash materials could be re-used before being discarded could be increased. The ability to re-use recycled water several additional times because these types of filters and/or batts are employed in the recycle process would result in a significant cost savings in the operation of car washes.

MOP HEAD FABRICS

[0214] Mop head fabrics can be of fibers in yarns, knitted fabrics, woven fabrics or non-woven fabrics. Mop head fabrics are subject to bacterial and fungal growth due to their constantly being wetted upon use, and are left wet in storage and allowed to air-dry. This constant wetting also causes the development of odors and the eventual deterioration of the integrity of the mop head materials themselves. Mop heads can transfer bacteria and fungi from one area to another and thus can be the cause of significant collections of microbes and fungi.

Thus, these mop head fabrics made from anti-microbial materials significantly reduce the growth of mold, mildew, and bacteria. By achieving this goal, odors associated with the long-term use of these materials are reduced. Also, the number of times they may be re-used before being discarded is increased, both because of the incorporation of anti-microbial fibers into these materials and the strengthening strategies indicated above. These characteristics also result in a significant costs savings in the use of mop heads in industrial settings.

DUST MASKS

[0215] Dust masks are vulnerable to the capture and seeding of bacteria and fungi. They can provide hospitable sites for the protected growth and the inhalation/exhalation of microbes. These products benefit from having anti-bacterial and anti-fungal agents incorporated into them. Dust masks may be of a nonwoven construction of anti-microbial fibers (at least in part) and may be covered on one or both sides with a fabric layer. Such masks which can have or provided anti-microbial containing filters are useful in reducing the build-up of biological materials on the dust mask which could be inhaled by the user. Both bi-component fibers and mixed fiber fabrics are useful embodiments for dust masks. Other agents may be used as disclosed herein. [Fos P51]

FIBROUS MEDIA

[0216] Humidifier evaporation surface media introduces an anti-microbial fiber into the evaporation surface media for humidifiers. Such a media prevents the growth of mold, mildew, bacteria, and fungi on the media. Preventing such growth reduces or eliminates the "musty smell" currently experienced when such devices are started up to humidify home or office environments. It reduces or prevents the growth of organisms in humidifier systems to prevent odor and bacterial growth. The media may be made of a nonwoven fibrous material made at least in part of the anti-microbial fibers disclosed herein. **FIG. 12** is a schematic view of a humidifier evaporation surface media, which is made at least in part of anti-microbial fibers, used to humidify air. **FIG. 13** shows a humidifier pad which could float on the surface of a tank, be attached to the bottom or sides of the tank, or in the suction or discharge sides of the circulation pump, and it is made at

least in part of the anti-microbial fiber disclosed herein. **FIG. 14** shows a "fish tank" circulation/aeration system. An anti-microbial pad or filter is on the suction or discharge side of the pump or attached to the bottom on the sides of the tank. This helps prevent the growth of microbes in recirculation systems and tanks which can not use chemicals or in which it is desired not to use chemicals. This and other uses for anti-microbial fibers in different environments show that a person working , for example, in a moldy or dirty environment would want as much assistance as possible in a respirator or filter or mask. Also, one wants the anti-microbial agent to remain in the fiber and not be inhaled by the user.

BOAT BILGE PADS

[0217] Boat bilge anti-microbial pads can be made at least in part with anti-microbial fibers can be used in a filter in the system or can be used in a manner similar to that of the car wash filter in pads which are placed into the water storage tank to kill bacteria in the water.

[0218] It will now be apparent to those skilled in the art that other embodiments, improvements, details, and uses can be made consistent with the letter and spirit of the foregoing disclosure and within the scope of this patent, which is limited only by the following claims, construed in accordance with the patent law, including the doctrine of equivalents.

[0219] What is claimed is: